

National Aeronautics and  
Space Administration



# Southern Bhutan Ecological Forecasting

Modeling Asian Elephant (*Elephas Maximus*)  
Habitat Suitability along the Southern Bhutan  
Border with NASA Earth Observations

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DEVELOP

Maryland - Goddard | Summer 2020



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Image Credit: Bhutan Foundation

# COMMUNITY CONCERNS



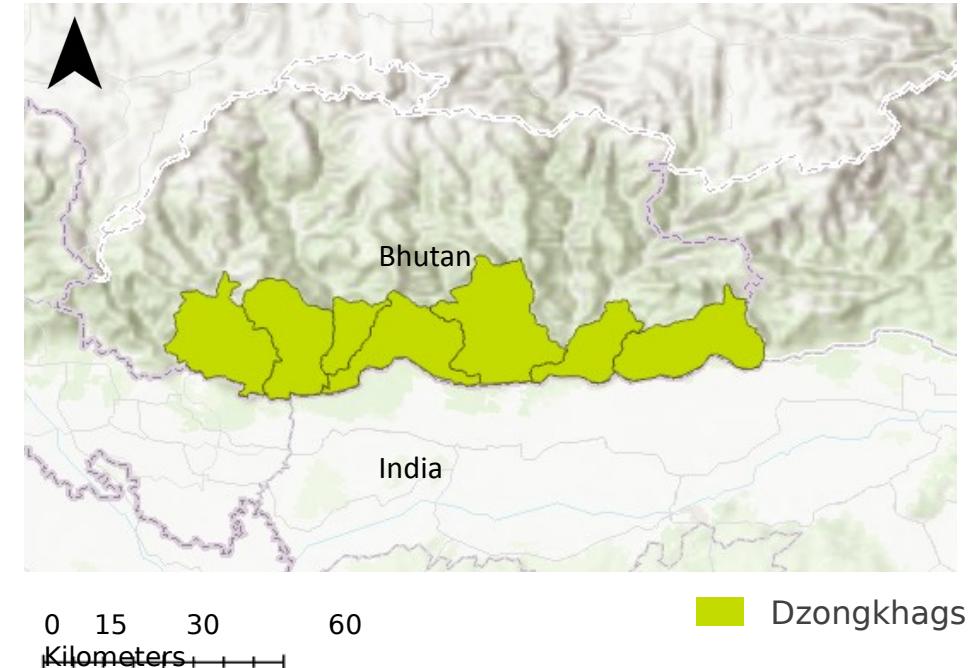
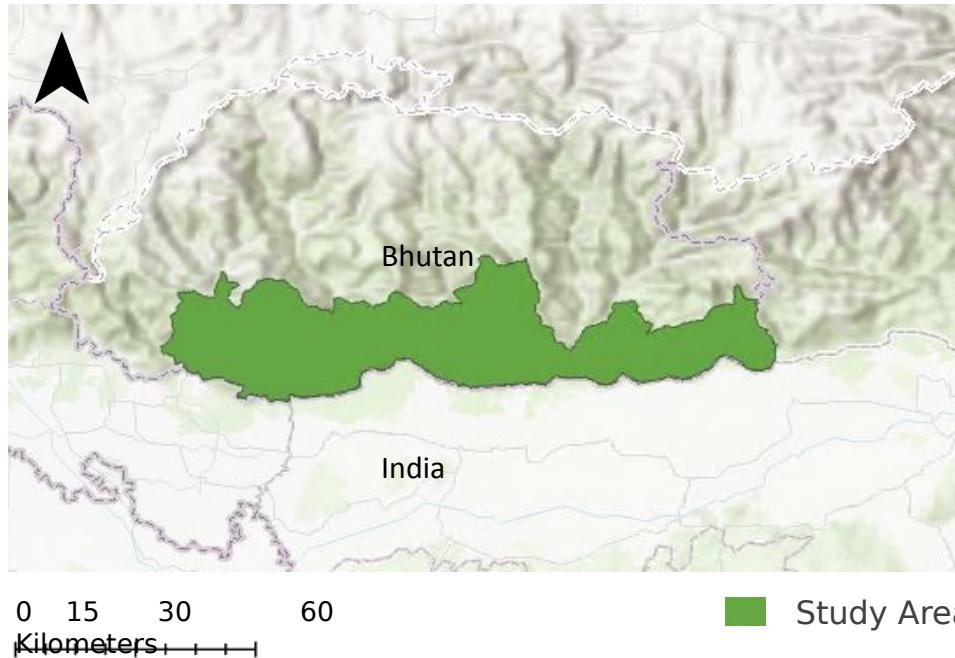
Image Credit: Bhutan Foundation

- ▶ Asian elephants (*Elephas maximus*) are a flagship species
- ▶ Environmental engineers
- ▶ Human Elephant Conflicts (HECs) in Bhutan
- ▶ Bhutan's Elephant conservation plan 2019

# PROJECT BACKGROUND



- ▶ Study Area: Southern Bhutan border
- ▶ Study Period: 1999 to 2019 (January through December)
- ▶ Partners: Bhutan Foundation and Bhutan Tiger Center



# OBJECTIVES



- ▶ Produce **Land Use and Land Cover** Classification maps
- ▶ Analyze and create an **Elephant Habitat Suitability Model** which will help in identifying areas needing wildlife corridors



Image Credit: Bhutan Foundation

# NASA SATELLITES/SENSORS USED



## ► NASA Earth Observations



Landsat 5



Landsat 8



SRT  
M



Terra MODIS

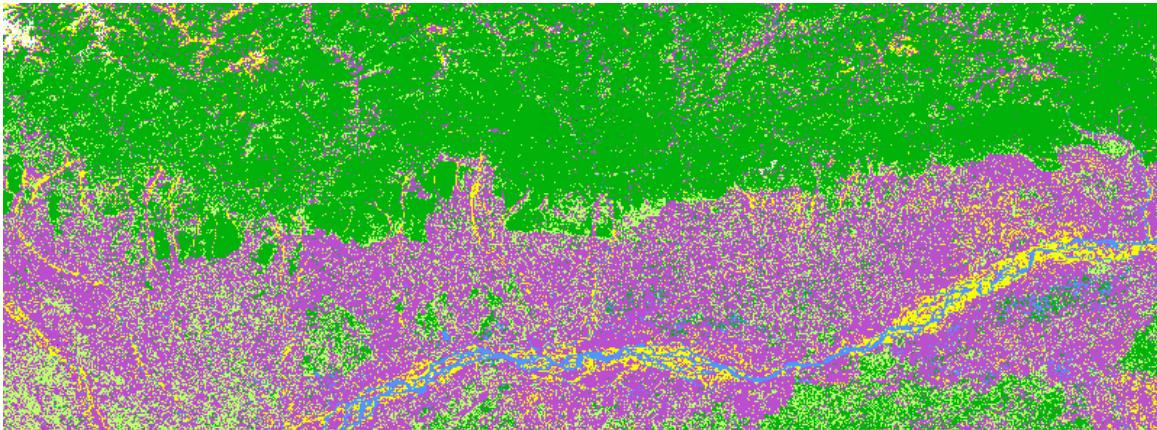
- Socioeconomic Data and Application Center (SEDAC)
- Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS)

# METHODOLOGY

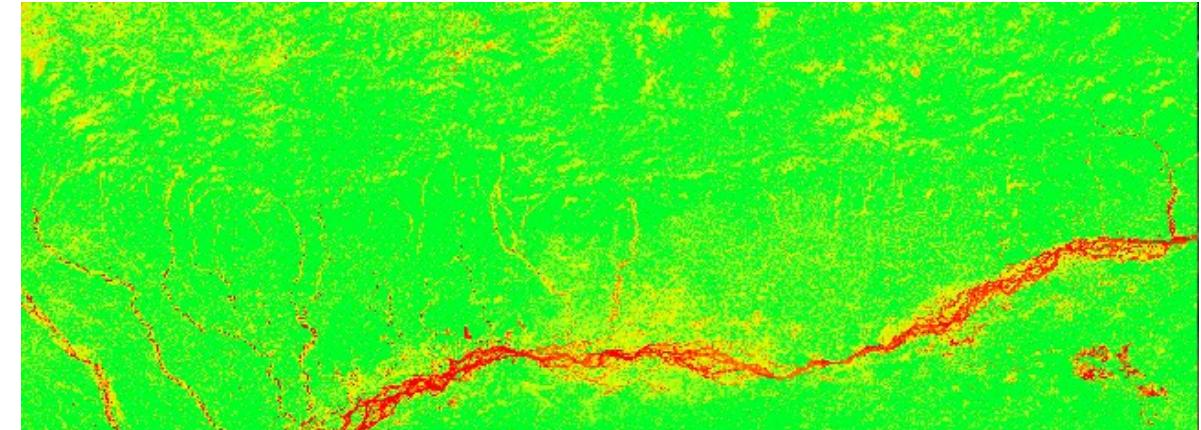


## Data Acquisition

- ▶ Land Cover Land Use
- ▶ Normalized Difference Vegetation Index (NDVI)



Land Cover Land Use (Landsat)

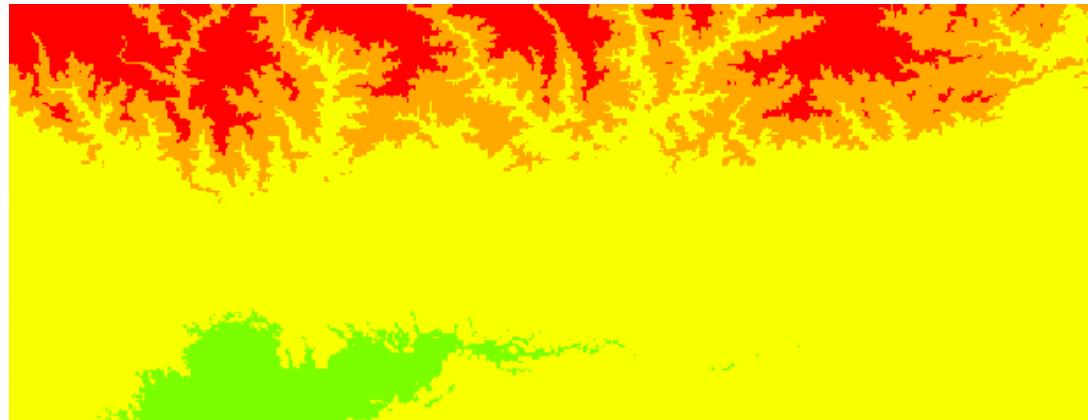


NDVI Phenology (Landsat)

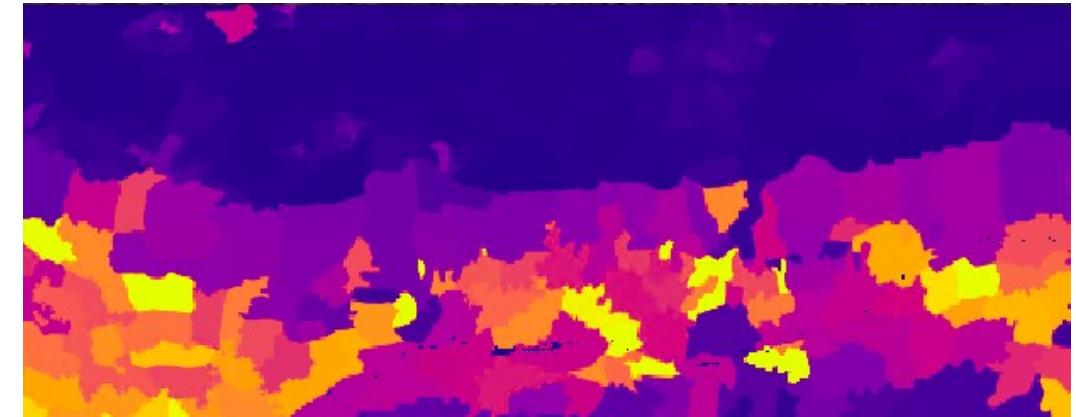
# METHODOLOGY



- ▶ Distance to Road and Urban Settlements
- ▶ Elevation and Slope
- ▶ Precipitation
- ▶ Water Sources/Distance to Water
- ▶ Population Density
- ▶ Land Surface Temperature



Elevation (SRTM)

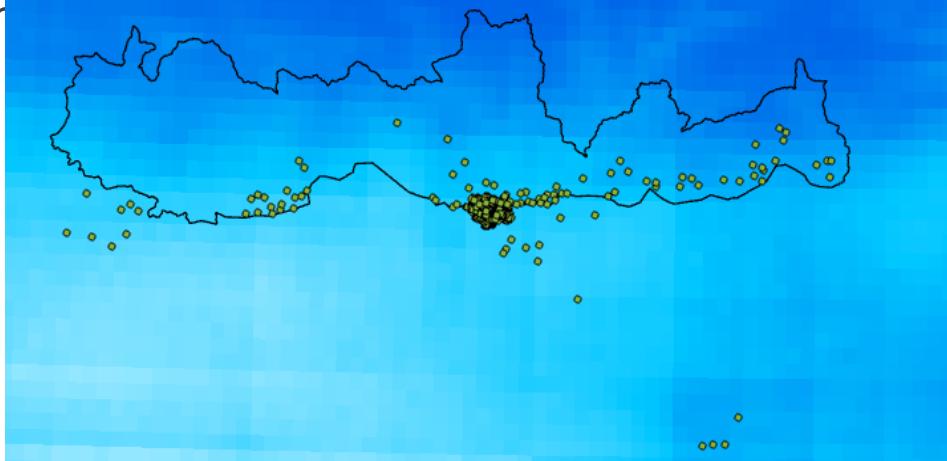


Population Density  
(SEDAC)

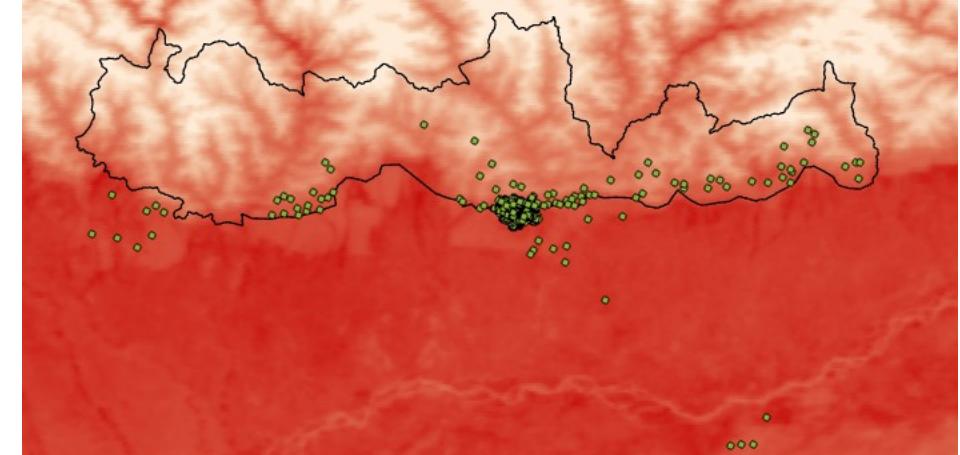
# TRAINING



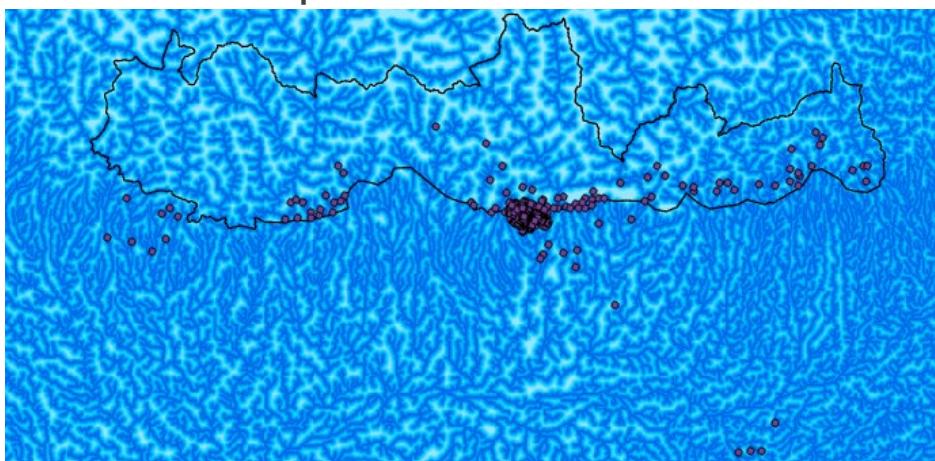
Maps of environmental variables compared to elephant occurrence



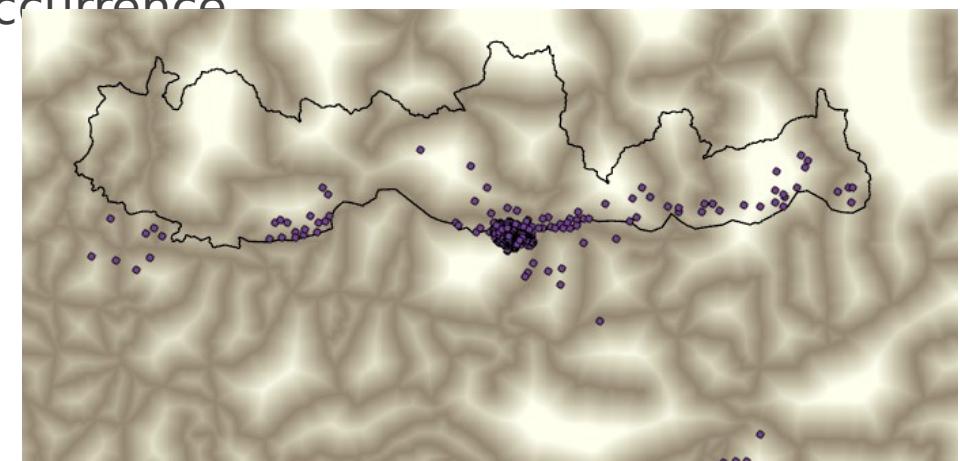
Annual Average Precipitation vs.  
Elephant Occurrence



Annual Average LST vs. Elephant  
Occurrence



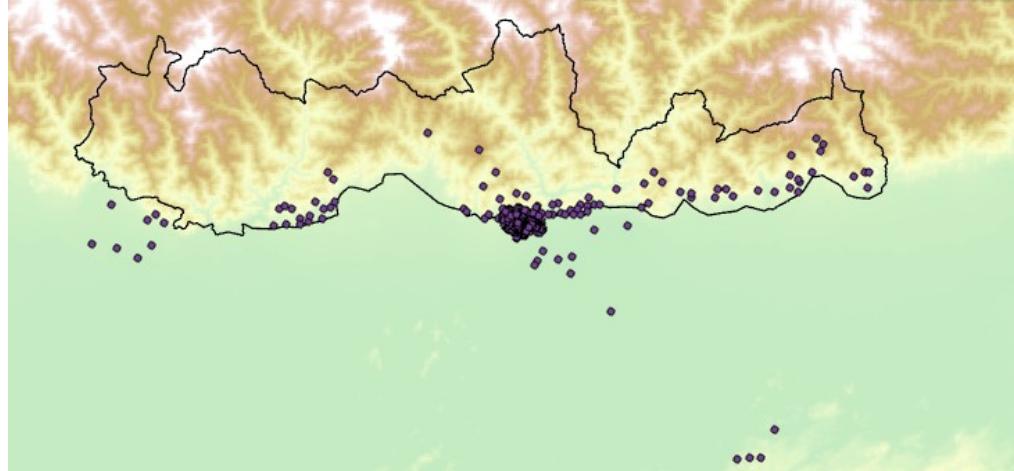
Distance to Rivers vs. Elephant  
Occurrence



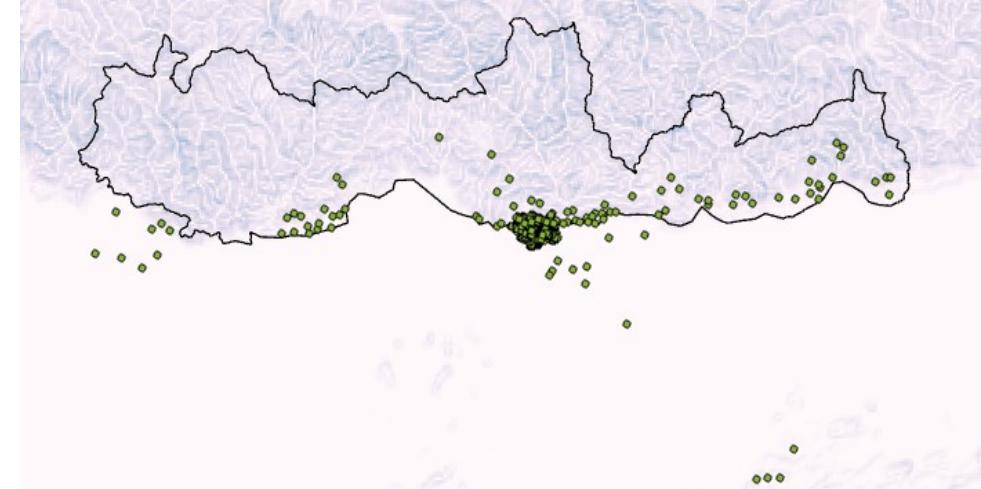
Distance to Roads vs. Elephant Occurrence

# TRAINING

## DATA



Elevation vs. Elephant occurrence



Slope vs. Elephant Occurrence

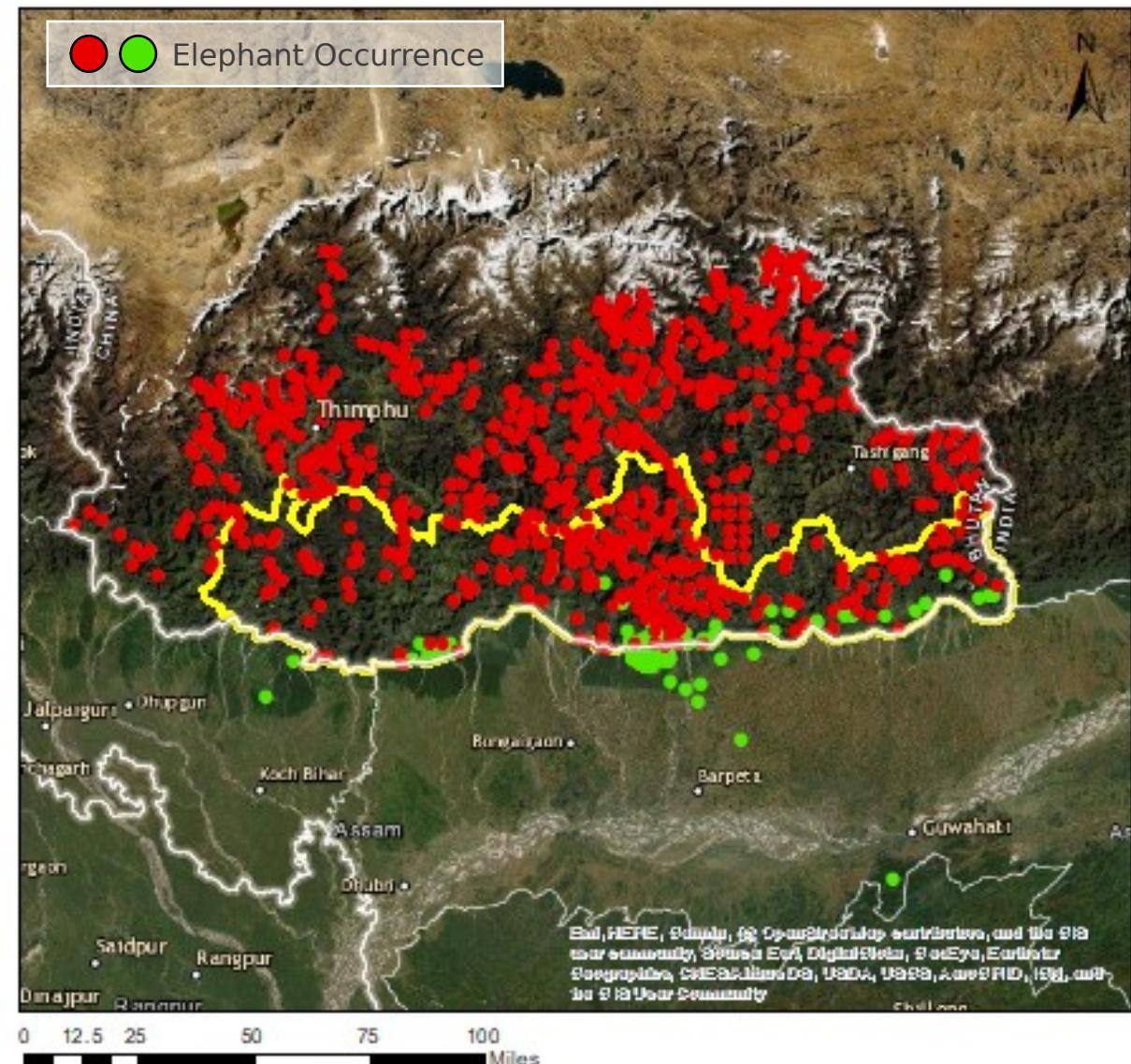


Population Density vs. Elephant  
Occurrence

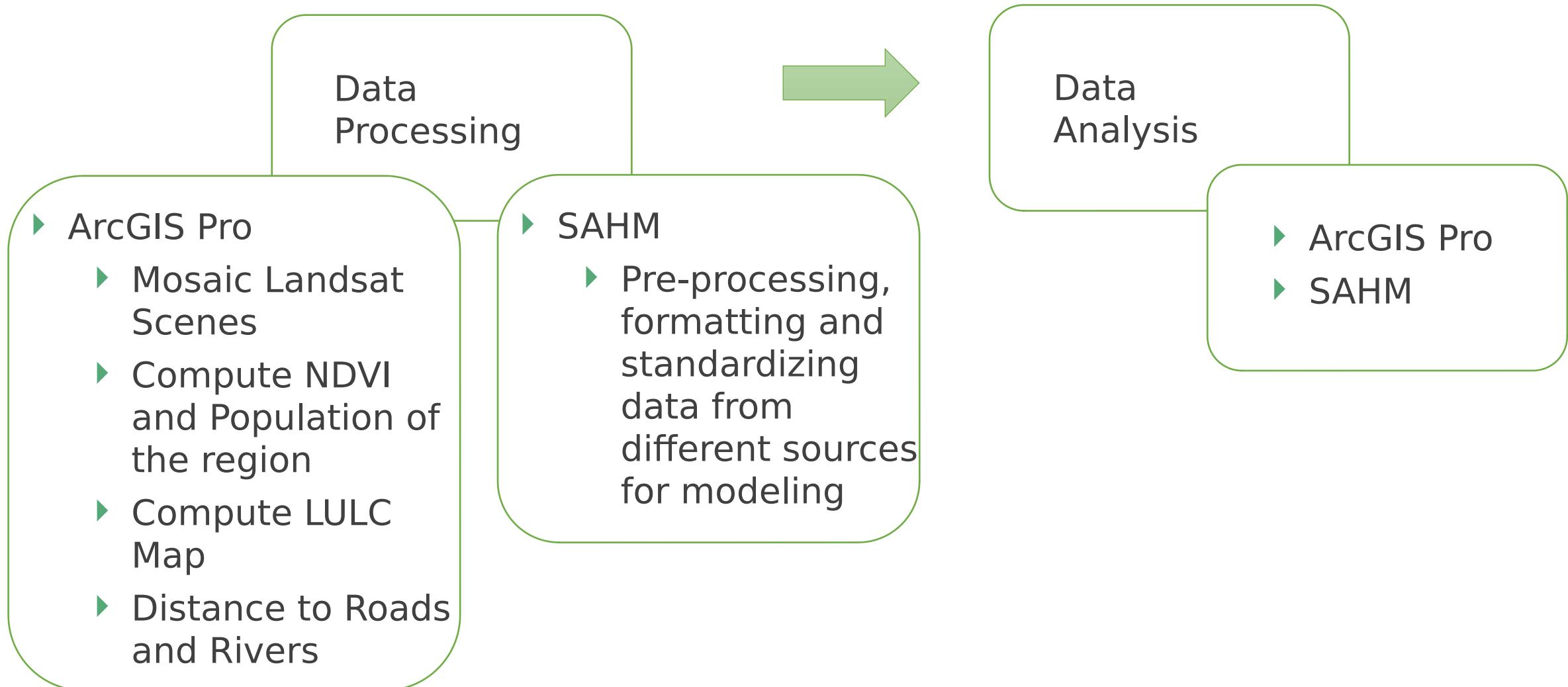
# TRAINING DATA



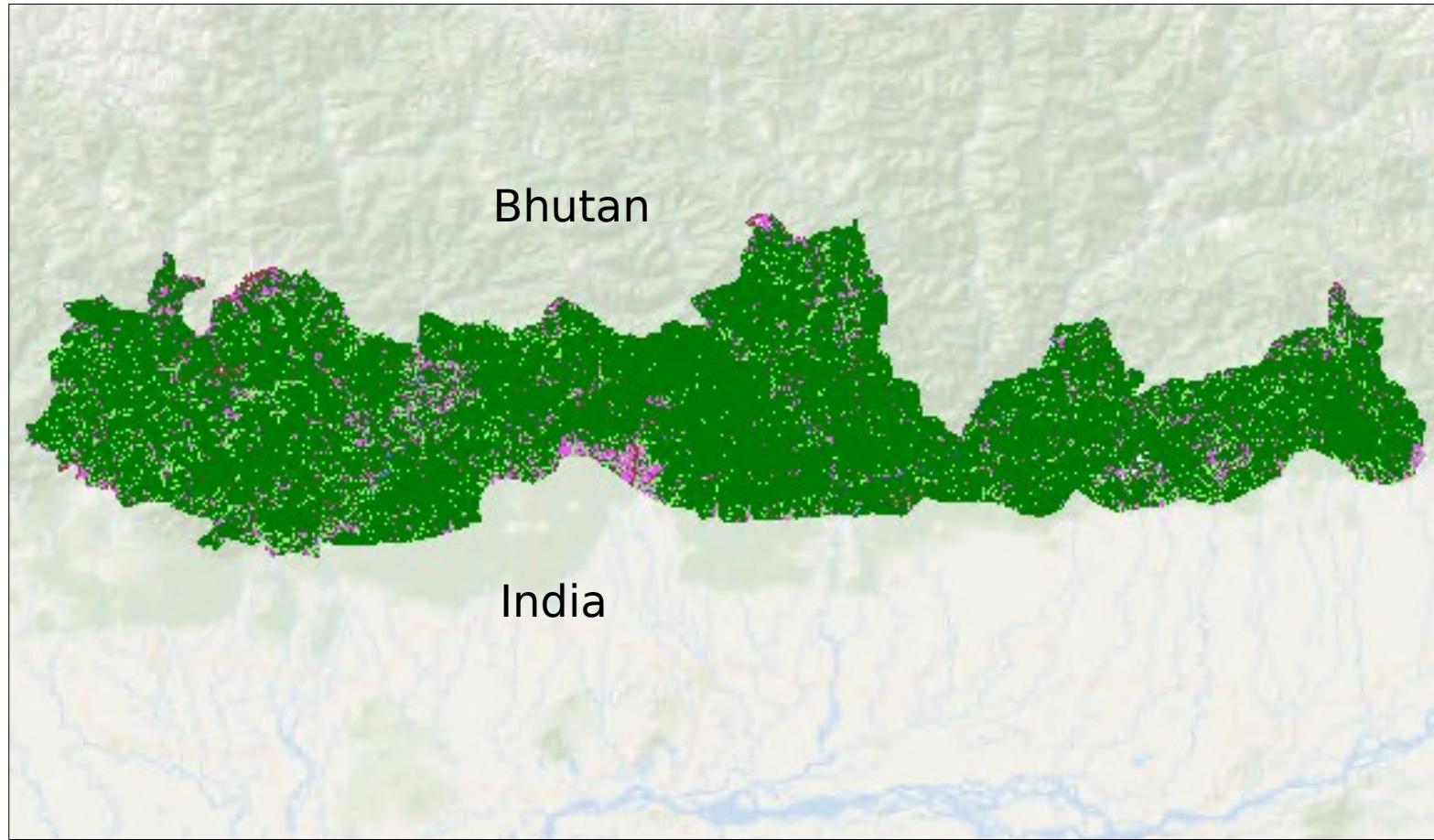
- ▶ 50 m buffer between predictors
  - ▶ Even split training data 759 P, 759 A
    - ▶ Original P:A ratio of 2:1
    - ▶ Ratio rebalanced with presences randomly selected from buffered training set
    - ▶ Notice high clustering and low spatial distribution of presences



# METHODOLOGY



# RESULTS - 2019 Land Cover Classification

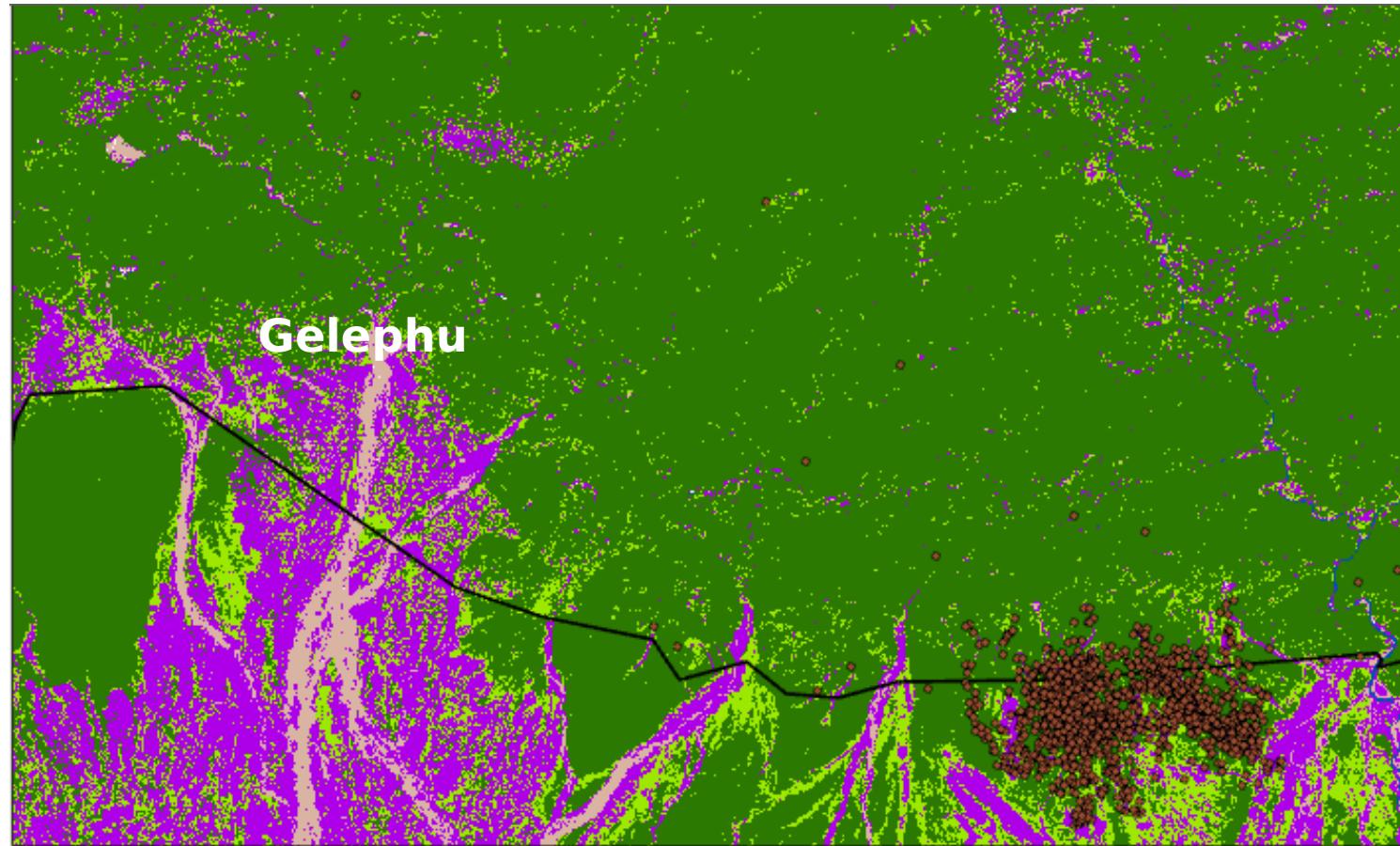


- Immature Forests
- Cultivated Area
- Barren Land
- Mature Forests
- Water
- Snow

0 16 32  
64 Kilometers



# RESULTS - 2019 Land Cover Classification

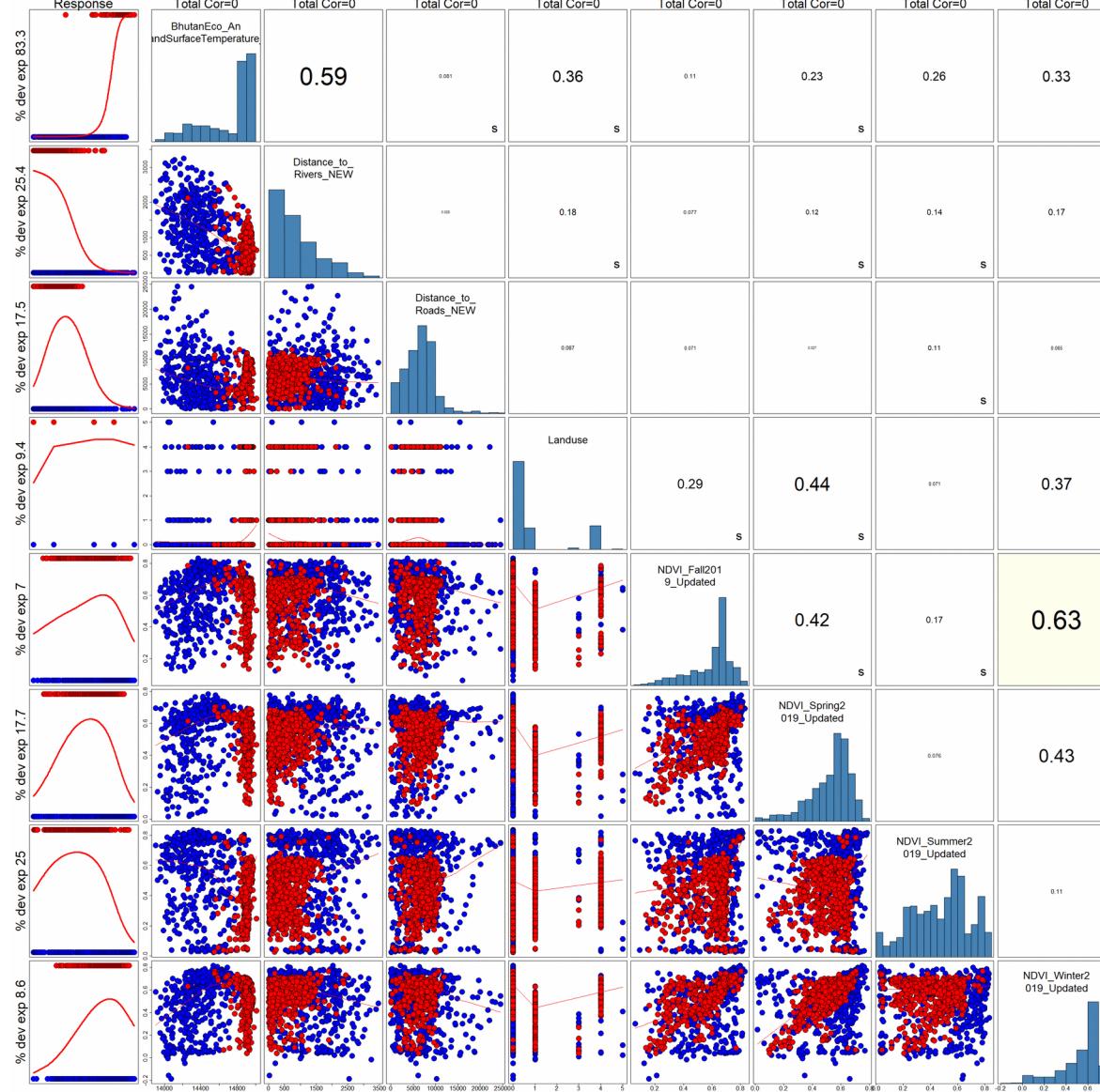


- Immature Forests
- Cultivated Area
- Barren Land
- Mature Forests
- Water
- Snow
- Elephant Occurrence

0 3 6 12 Kilometers



# RESULTS - Correlated Variables

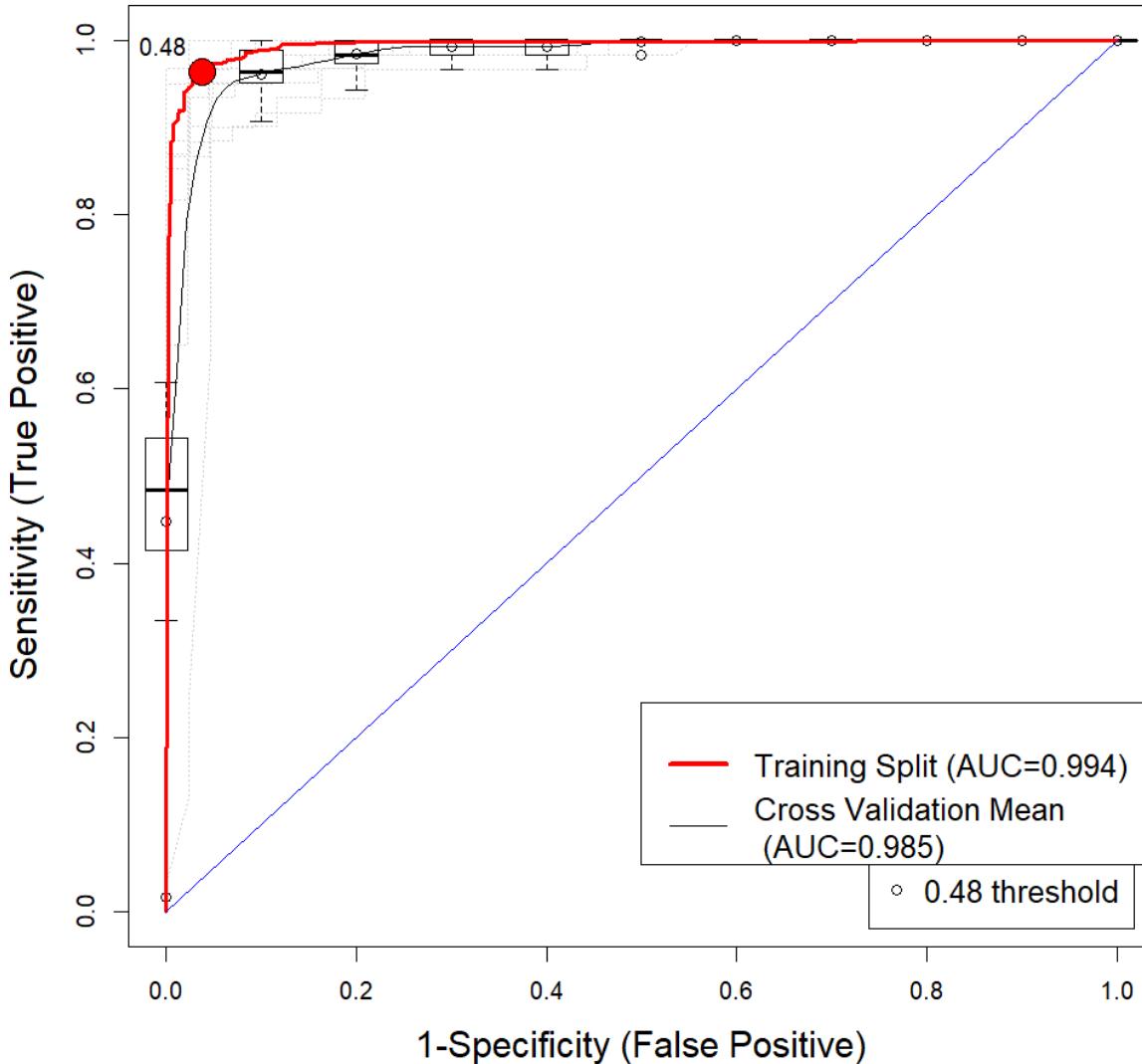


- ▶ Correlated variables over .70 were dropped
  - ▶ Slope
  - ▶ Elevation
  - ▶ Precipitation

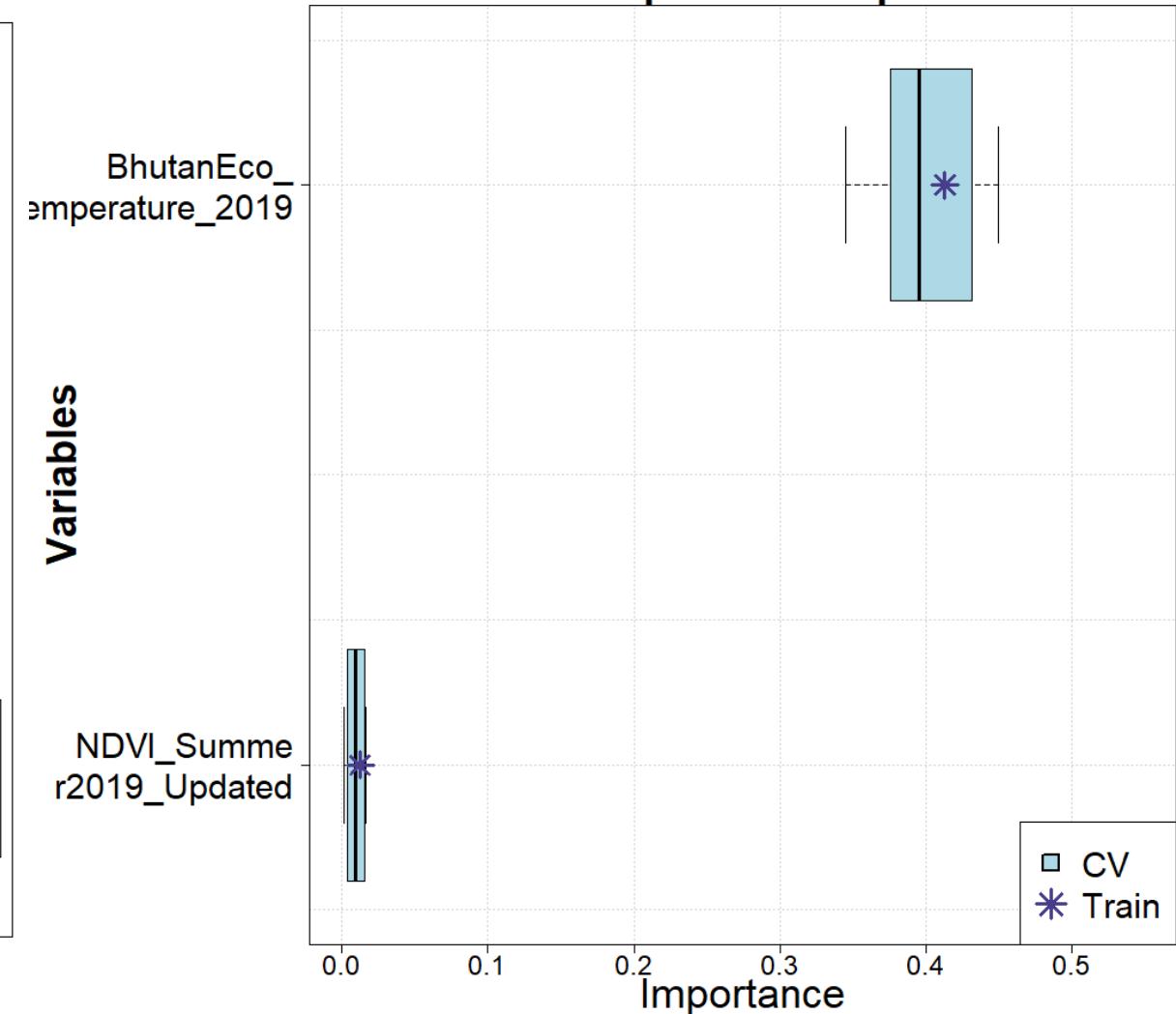
# Boosted Regression Tree Evaluation



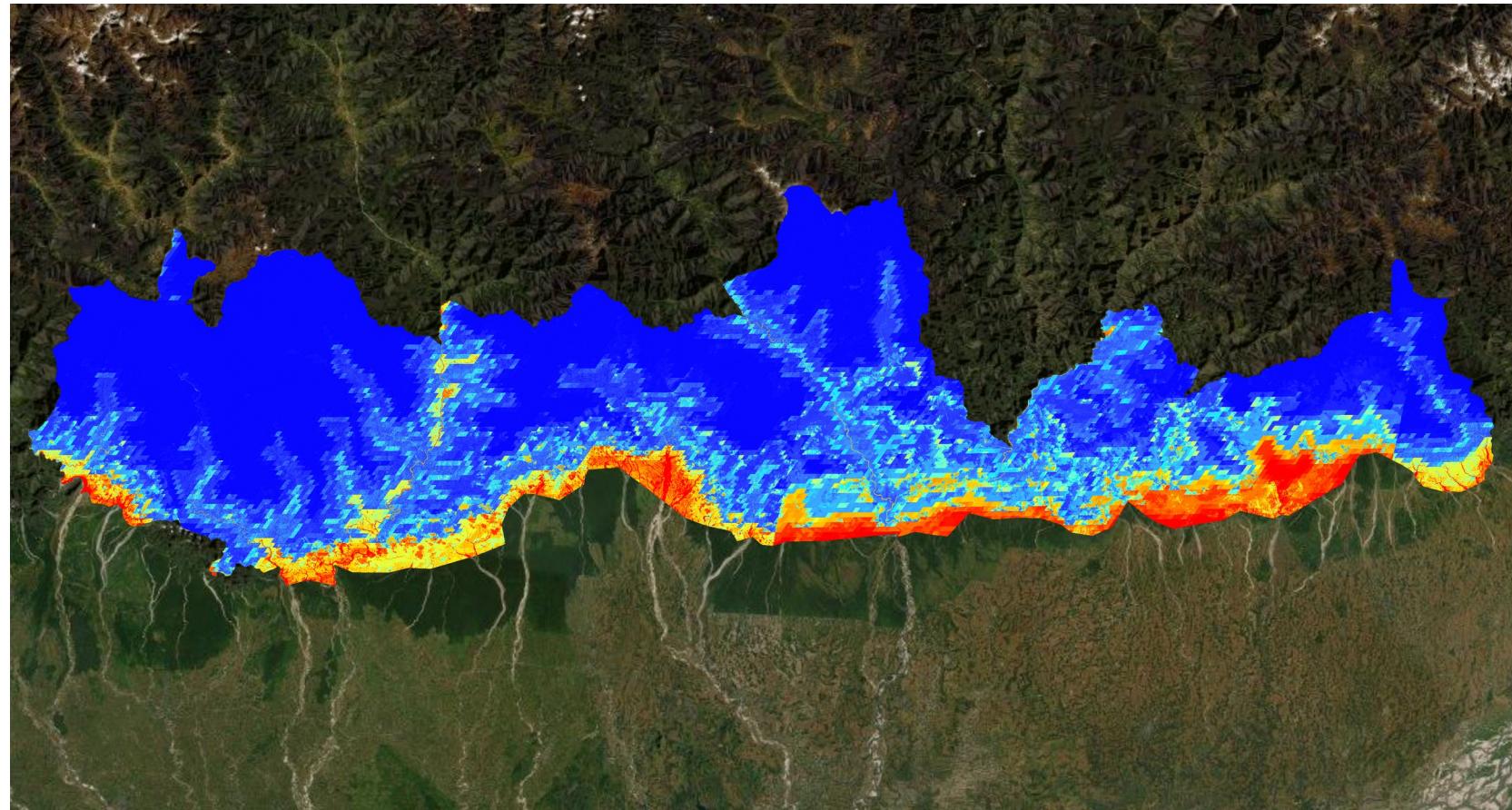
## ROC Plot for Cross-Validation



## Importance using the change in AUC when each predictor is permuted



# Boosted Regression Tree Probability Map



**Elephant Occurrence**

**LO**



**HIGH**

**W**

30      60      120      180

**240**



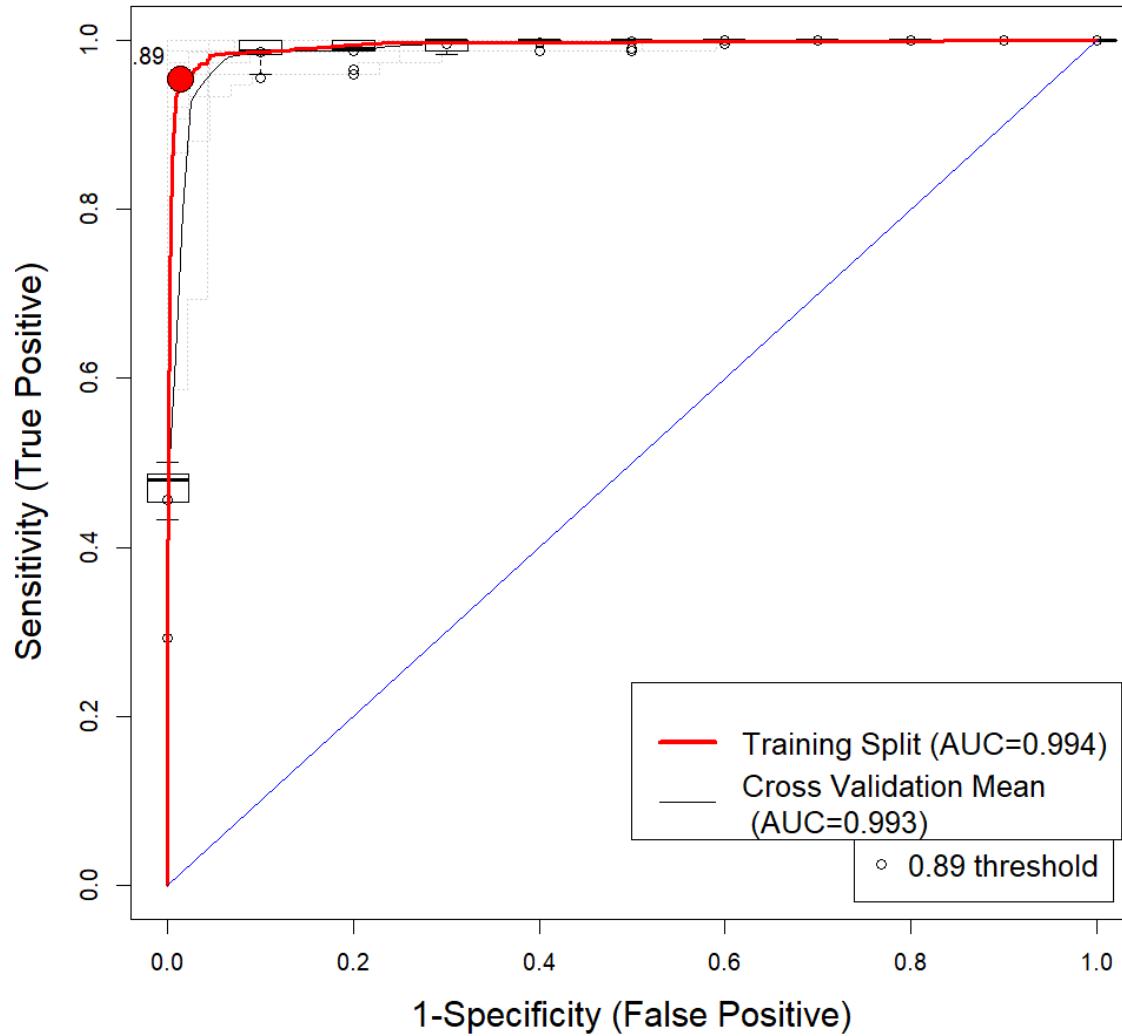
Kilometers



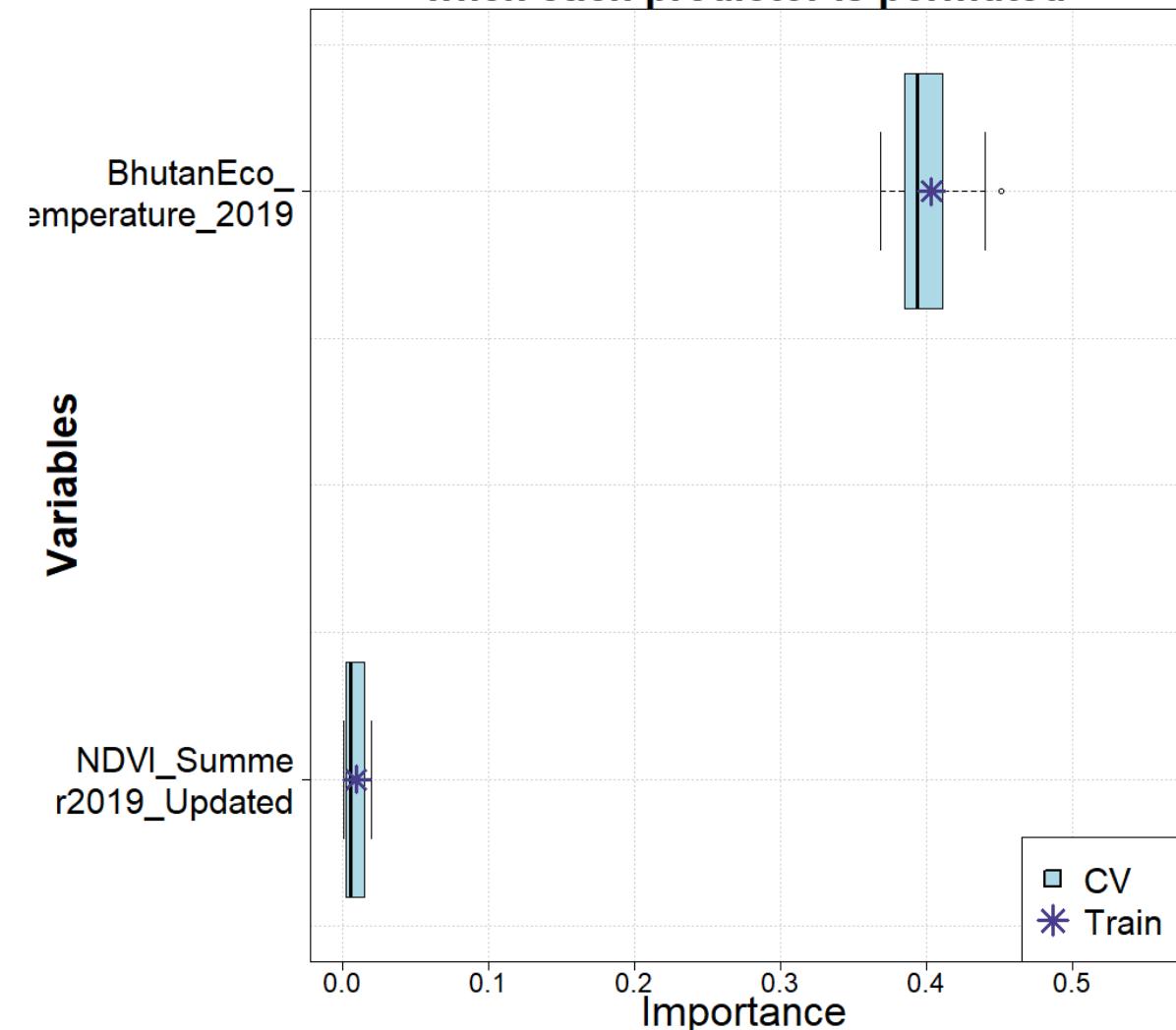
# Generalized Linear Model Evaluation



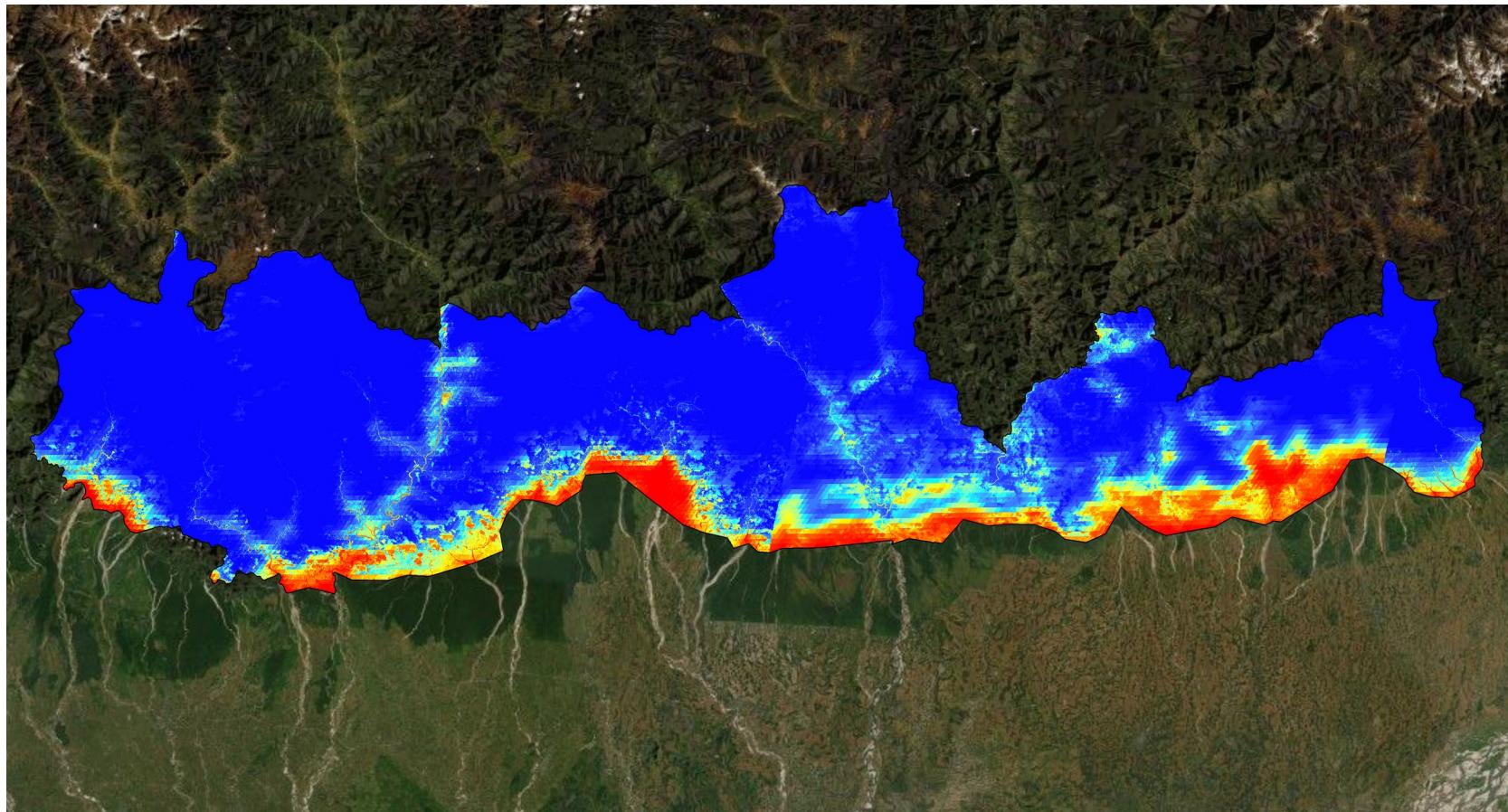
## ROC Plot for Cross-Validation



## Importance using the change in AUC when each predictor is permuted



# Generalized Linear Model Probability Map



**LO**



**HIGH**

**W**

30

60

120

180

240

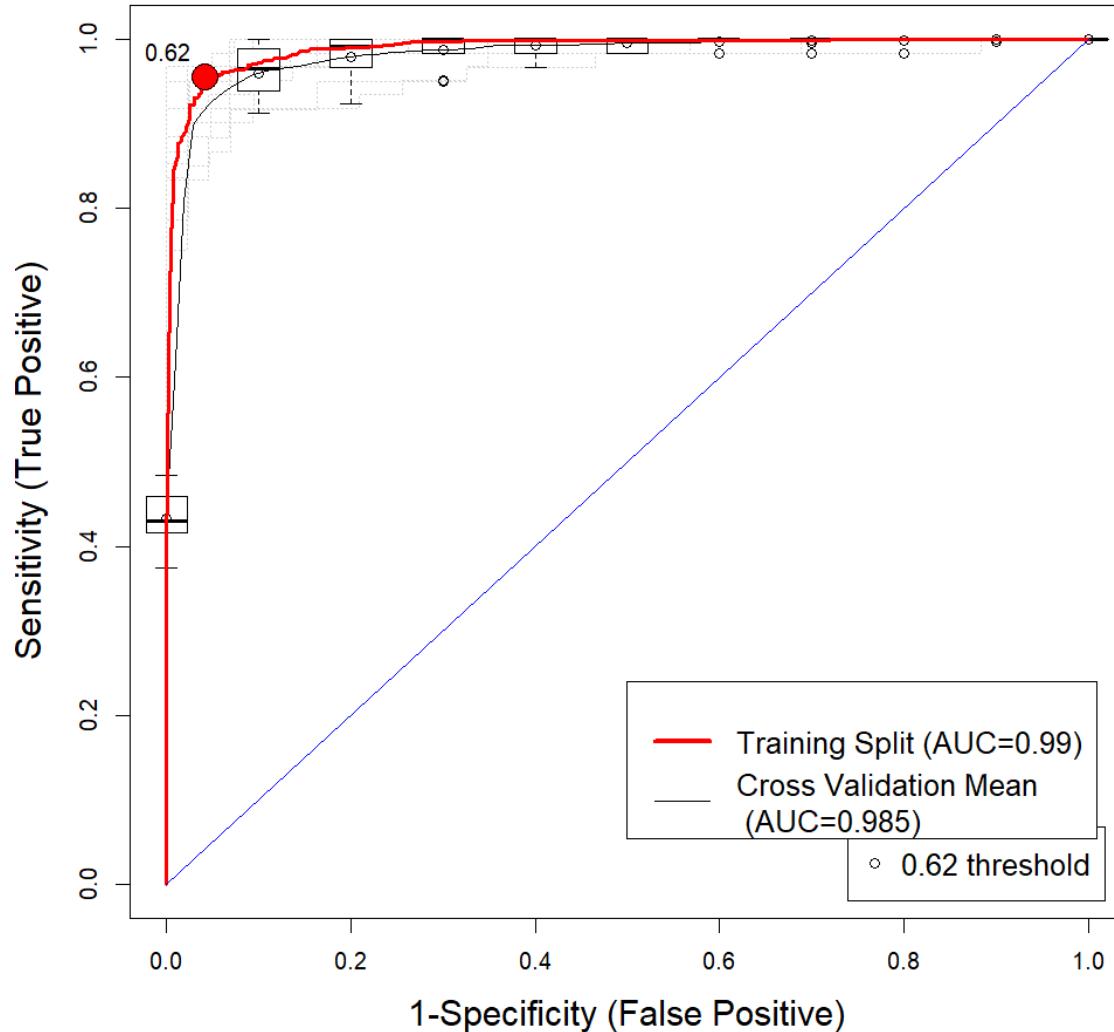
Kilometers



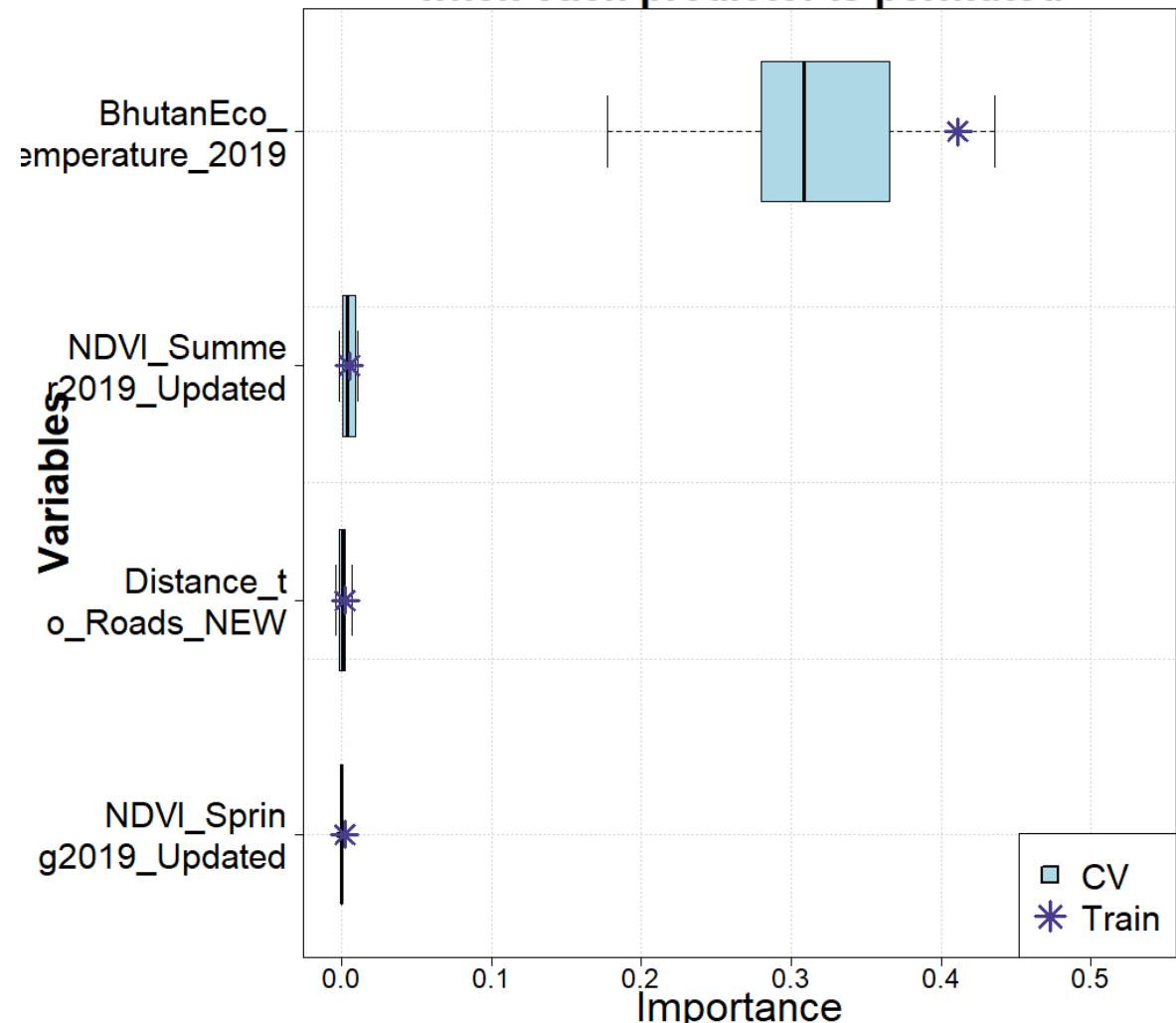
# Multivariate Adaptive Regression Splines Evaluation



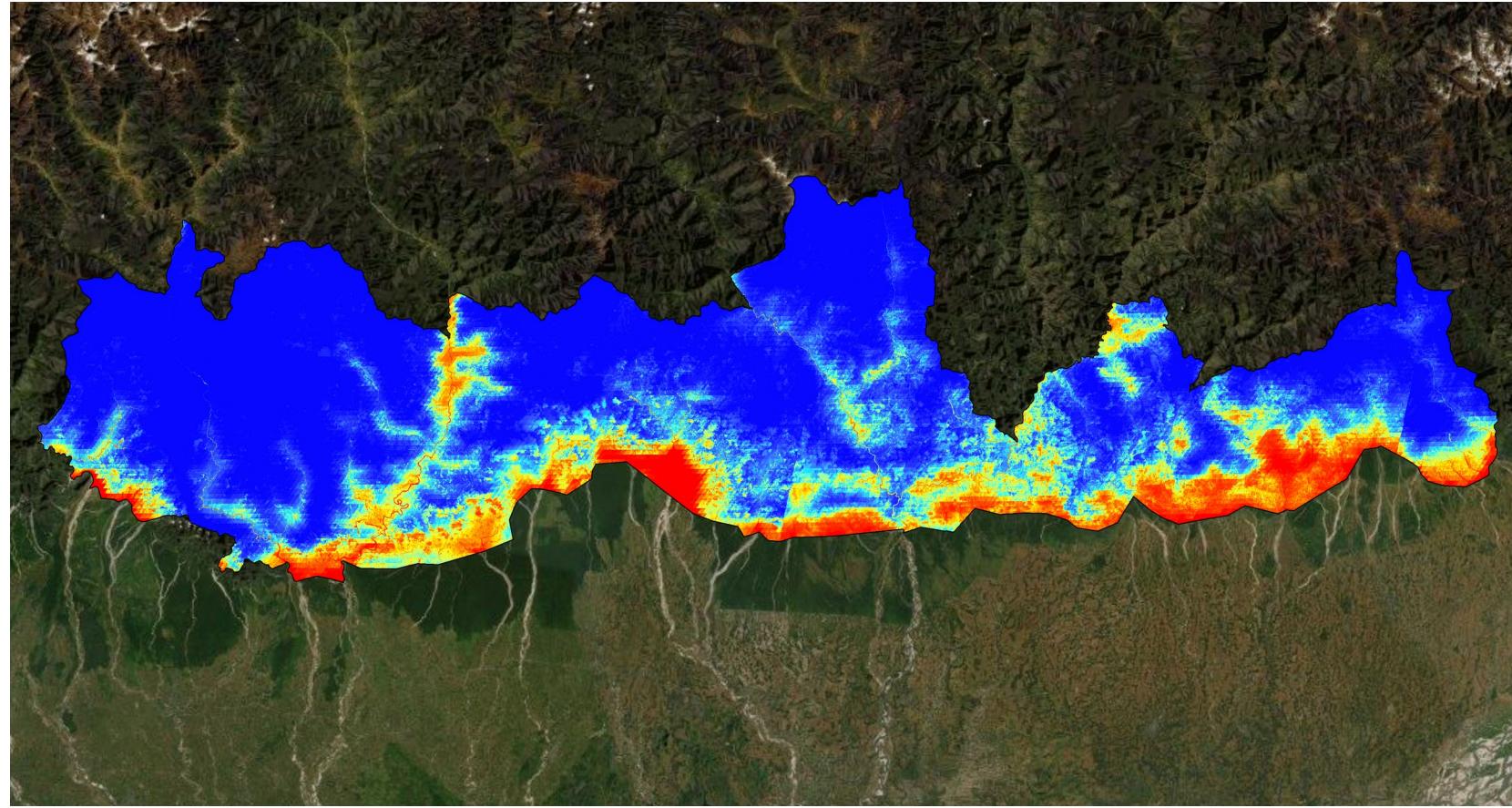
## ROC Plot for Cross-Validation



## Importance using the change in AUC when each predictor is permuted



# Multivariate Adaptive Regression Splines Probability Map



**LO**



**HIGH**

**W**

30

60

120

180

240

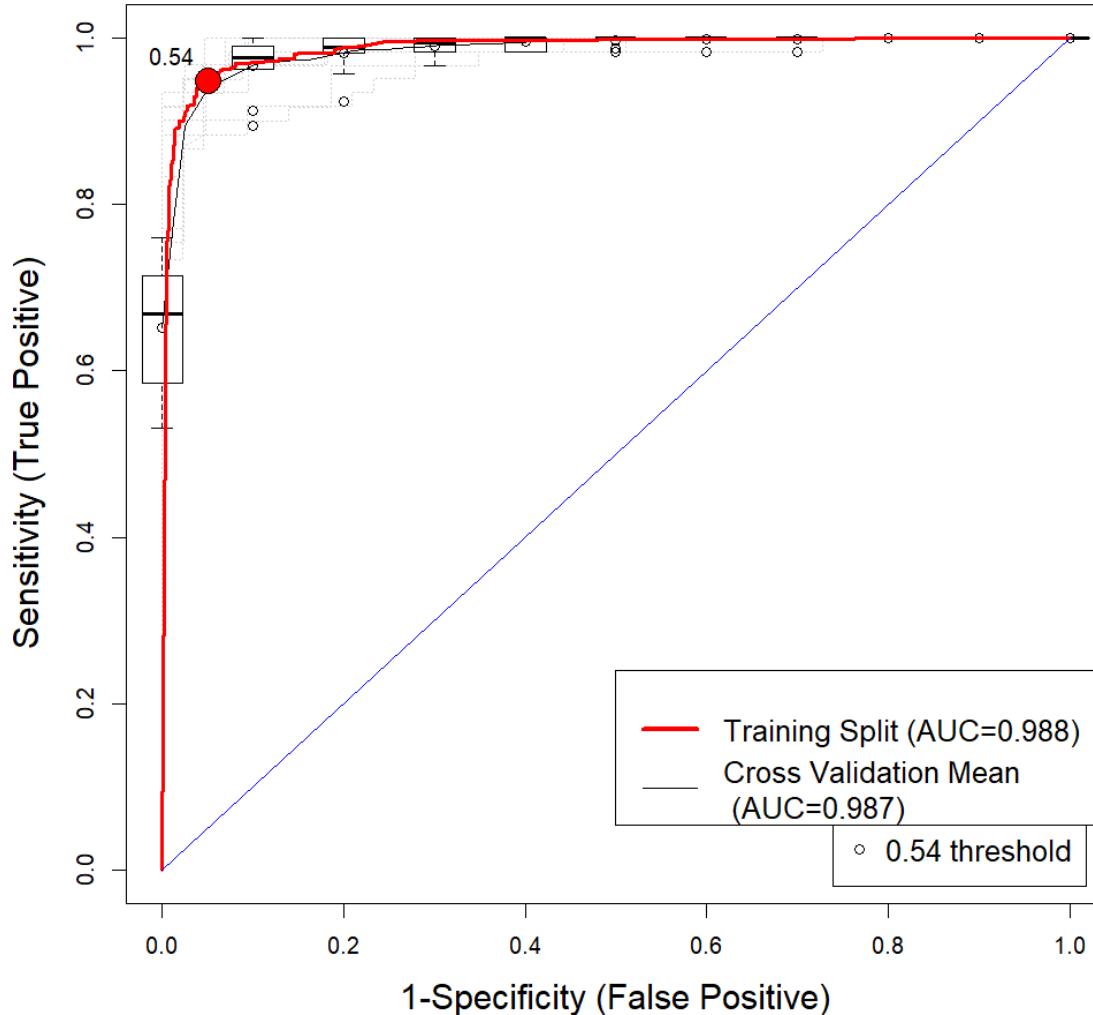
Kilometers



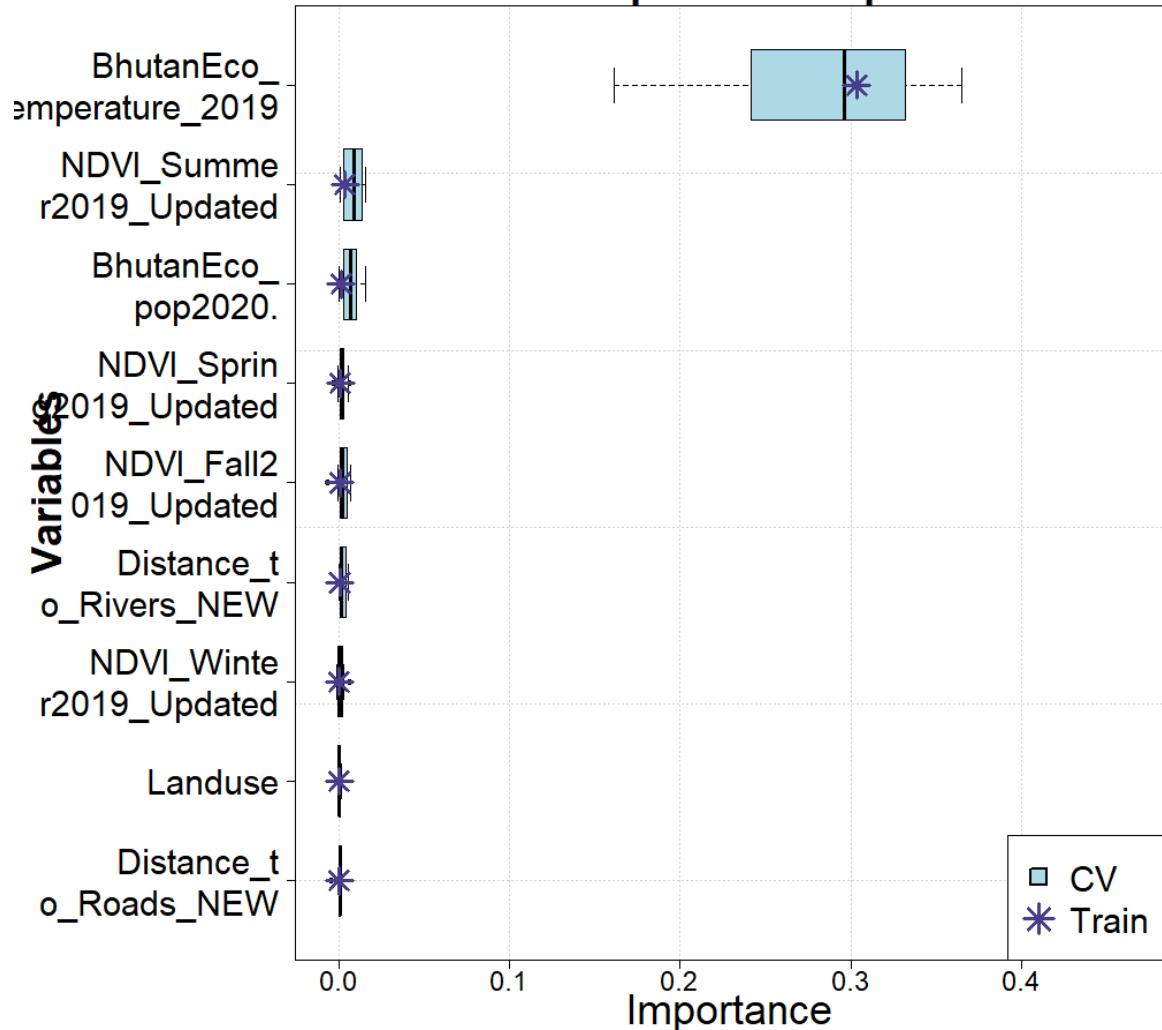
# Random Forest Evaluation



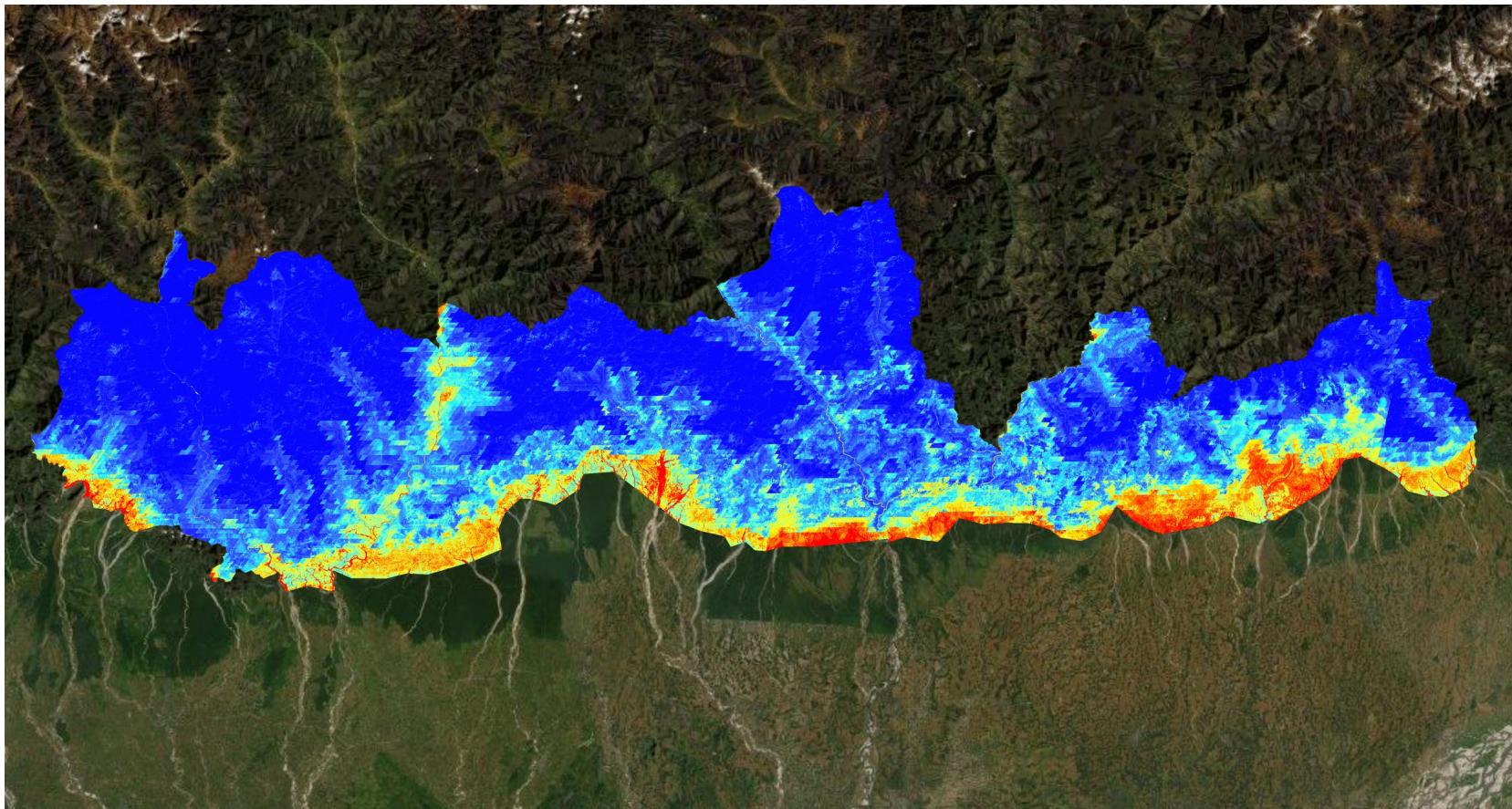
ROC Plot for Cross-Validation



Importance using the change in AUC  
when each predictor is permuted



# Random Forest Probability Map



LOW



HIGH

0W

30

60

120

180

240

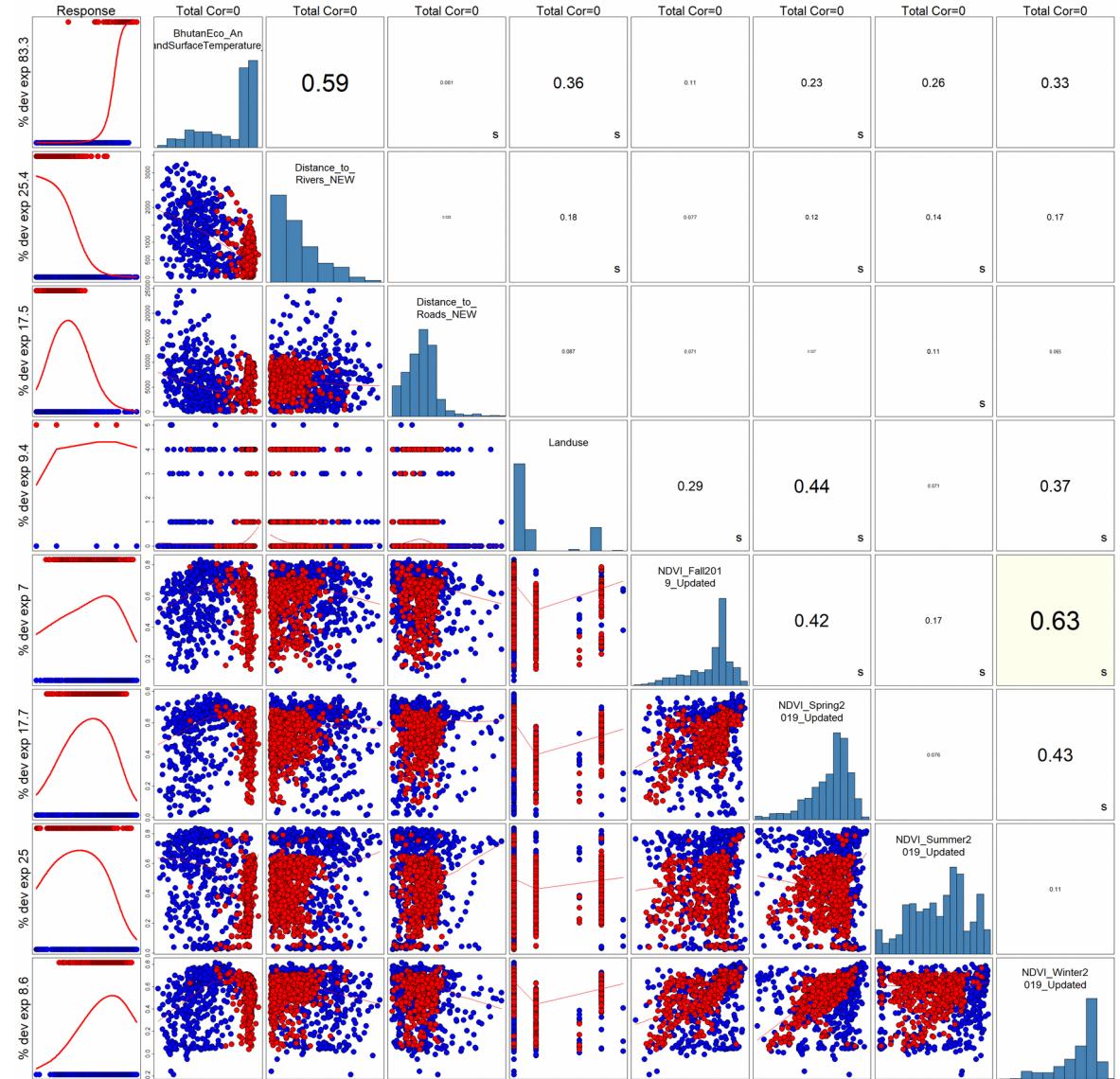
Kilometers



# ERRORS & UNCERTAINTIES



- ▶ Sampling bias of elephant occurrence data
  - ▶ Crowd-sourced data from GBIF
  - ▶ Highly correlated variables



# CONCLUSIONS



Image Credit: Adam Singer

- ▶ LST, slope, and elevation are **highly correlated predictors** in the model
- ▶ Suitability maps **suggest** where more camera traps can expand understanding
- ▶ Results indicate **importance of roads and waterways** to elephant occurrence
- ▶ Results can help **reduce HEC** in Southern Bhutan

# FUTURE WORK



- ▶ **Input** additional data (elephant presences and absences) and model variables (disturbance, tree cover)
- ▶ **Refine** land cover land use analysis
- ▶ **Analyze** historic and future data for Habitat suitability
- ▶ **Improve** models, methods, and data products can be provided to project end-users, building off results for the initial study



Image Credit: Adam Singer

# ACKNOWLEDGEMENTS

DEVELOP

- ▶ Joe Spruce (SSAI Research Consultant, Diamondhead, MS)
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